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Operator Contacted:	Amy Thurlkill		
Company:	Powertech (USA), Inc.		
Telephone:			
Staff Signature:	\s/		

Eric,
Yes, Eric
we resubmitted the notary page to be used for the completed application.

The Myrick et al, table is attached.
We obtain signed receipts from Fed Ex.

I will double check for Michals. The return receipts were not requested, however proof of mailing was. We will send the signed return receipts to your office. The proof of filing will be sent to you the same time as the return receipt

Thank you so much,
Amy

Health Physics Vol. 45, No. 3 (September), pp. 631-642, 1983
Printed in the U.S.A.

0017-9078/83 $3.00 + .00
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DETERMINATION OF CONCENTRATIONS OF SELECTED RADIONUCLIDES IN SURFACE SOIL IN THE U.S.*

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(*Received* 15 *December* 1981; *accepted* 11 *September* 1982)

Abstract—Background radionuclide concentrations in surface soil across the U.S. have been measured by the Remedial Action Survey and Certification Activities Group of the Health and Safety Research Division at Oak Ridge National Laboratory (ORNL). These measurements have been made as part of the ORNL program of radiological surveillance at inactive uranium mills and sites formerly utilized during Manhattan Engineer District and early Atomic Energy Commission projects. The background soil sampling program involved determination of ^{226}Ra, ^{232}Th and ^{238}U concentrations in surface soil samples for comparative purposes to determine the extent of contamination present at the survey sites and surrounding off-site areas.

The sampling program to date has provided background information at 356 locations in 33 states. The nationwide average concentrations of ^{226}Ra, ^{232}Th and ^{238}U in surface soil were determined to be 1.1, 0.98 and 1.0 pCi/g, respectively. This paper summarizes the results of these background measurements and provides a brief analysis of regional differences and similarities in data values.

INTRODUCTION

In 1974, the Atomic Energy Commission (AEC) initiated a study of 22 inactive uranium mill sites in cooperation with the Environmental Protection Agency (EPA) and health authorities in the eight affected western states (DOE79; DOE81). This study developed into the Uranium Mill Tailings Remedial Action Program (UMTRAP), the purpose of which has been to conduct an engineering assessment of existing conditions at these sites, determine the remedial action required, develop plans and specifications for implementing remedial action, perform the necessary remedial action, verify the results and release the sites for unrestricted or limited use, as required. The Remedial Action Survey and Certification Activities (RASCA) Group of the Health and Safety Research Division at Oak Ridge National Laboratory (ORNL) provided radiological assessments of each of the 22 sites for the Energy Research and Development Administration [now the Department of Energy (DOE)]. To develop a basis for a radiological assessment of the impact that these sites had on their respective locations, natural background radiation levels in the affected western states were determined by ORNL.

In addition to the inactive mill locations, over 150 sites (primarily in the eastern U.S.) were involved in research, processing, and storage of radioactive ores and residues of the uranium and thorium decay chains during the early days of this country's development of nuclear energy. Work at these federally, privately, and institutionally owned facilities was directed by the Manhattan Engineer District (MED) and later the AEC. As a result of these activities, materials, equipment, buildings and land at these sites became contaminated, primarily with naturally occurring radionuclides from the uranium and thorium

*Research sponsored by the Environmental and Safety Engineering Division, U.S. Department of Energy, under Contract W-7405-ENG-26 with the Union Carbide Corporation.

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decay chains (DOE80). Contracts for needed services at each site were made and terminated as required. However, at termination, the sites were to have been decontaminated according to guidelines then in use. Most of these sites were decontaminated, but since that time, many of the radiological records have been lost. In addition, radiological criteria for the unrestricted release of these sites have become more stringent. A DOE program was initiated in 1977 to identify all formerly utilized sites, characterize their current radiological status, determine the extent of remedial action (if necessary), perform the required remedial measures, and release the sites for unrestricted or limited use, as appropriate. This program is called the Formerly Utilized MED/AEC Sites Remedial Action Program (FUSRAP). The ORNL-RASCA Group has assumed a major role in characterizing the current radiological status of these sites. As with the inactive uranium mill sites, background radiation levels were determined in the surrounding areas in order to understand the significance of radiation levels present at FUSRAP sites.

The continuing background measurement program at ORNL began in 1975. Since that time, concentrations of ^{226}Ra, ^{232}Th and ^{238}U in surface soil samples have been determined at 356 locations in 33 states. This paper summarizes the results of the measurement program and provides a brief analysis of regional differences and similarities in data values.

METHODS

Soil sampling and radionuclide analysis

Background surface soil samples (top 6 cm of soil) were collected and approx. 600 cm^3 of soil was placed in a plastic bag for each sample. All samples were returned to ORNL, where they were dried for 24 hr at 110°C and then pulverized to a particle size no greater than 500 μm in diameter (−35 mesh). A 30-cm^3 aliquot of the pulverized sample was then sent to the Analytical Chemistry Division at ORNL for ^{238}U concentration analysis by neutron absorption techniques (Dy62). This analysis involves irradiation of the soil sample in the Oak Ridge Research Reactor with subsequent counting of delayed neutrons in a high-efficiency BF_3 counter. The sensitivity of this technique for ^{238}U is approx. 40 ppb (10^{-2} pCi/g), with an error of about ±3% at the 95% confidence level. Other aliquots from the pulverized sample were transferred to plastic bottles, weighed, and stored for approx. 30 days to allow buildup of radon and radon daughters. These aliquots were counted using a germanium lithium-drifted [Ge(Li)] detector, and the spectra obtained analyzed for the ^{226}Ra and ^{232}Th concentrations using computer curve-fitting techniques. The detector system is systematically calibrated using soil standards provided by New Brunswick Laboratory. These samples contain "certified" concentrations of ^{238}U and ^{232}Th (by weight), with associated daughter concentrations calculated assuming secular equilibrium. In identifying ^{226}Ra, six principal γ-ray lines are analyzed. Most of these are from the daughter product ^{214}Bi and correspond to 295, 352, 609, 1120, 1765 and 2204 keV. For analysis of ^{232}Th, seven γ lines of its daughters are analyzed (239, 338, 583, 795, 911, 969 and 2615 keV). With a 300-cm^3 sample and a graded shield developed for use with the system, it is possible to measure less than 1 pCi/g of ^{232}Th or ^{226}Ra with an error of ±10% or less. The minimum detectable concentration (MDC) for the system, considering the background of the counting system, is generally about 0.3 pCi/g.

LOCATIONS OF STATE BACKGROUND SAMPLES

The locations of the background soil samples in the U.S. are shown in Fig. 1. From this map, it is evident that these locations are nonrandom and are positioned along major highways. These locations were selected by several considerations: (1) proximity to or along a route to a site undergoing a radiological survey; (2) accessibility (i.e. closeness to highway); and (3) the degree to which the location was undisturbed. Locations were selected which appeared to have been uncultivated or at least fallow for a number of years. At the present time 33 states have been included in the sampling program. Those states are as follows:

ıent counting of delayed efficiency BF_3 counter. ıis technique for ^{238}U is pCi/g), with an error of ‰ confidence level. Other pulverized sample were ic bottles, weighed, and 30 days to allow buildup daughters. These aliquots g a germanium lithium-tector, and the spectra for the ^{226}Ra and ^{232}Th g computer curve-fitting ector system is systema-sing soil standards pro-ıswick Laboratory. These ertified" concentrations of weight), with associated tions calculated assuming . In identifying ^{226}Ra, six es are analyzed. Most of daughter product ^{214}Bi and 352, 609, 1120, 1765 and ysis of ^{232}Th, seven γ lines e analyzed (239, 338, 583, 2615 keV). With a 300-cm^3 d shield developed for use is possible to measure less 'h or ^{226}Ra with an error of minimum detectable con-for the system, considering f the counting system, is ; pCi/g.

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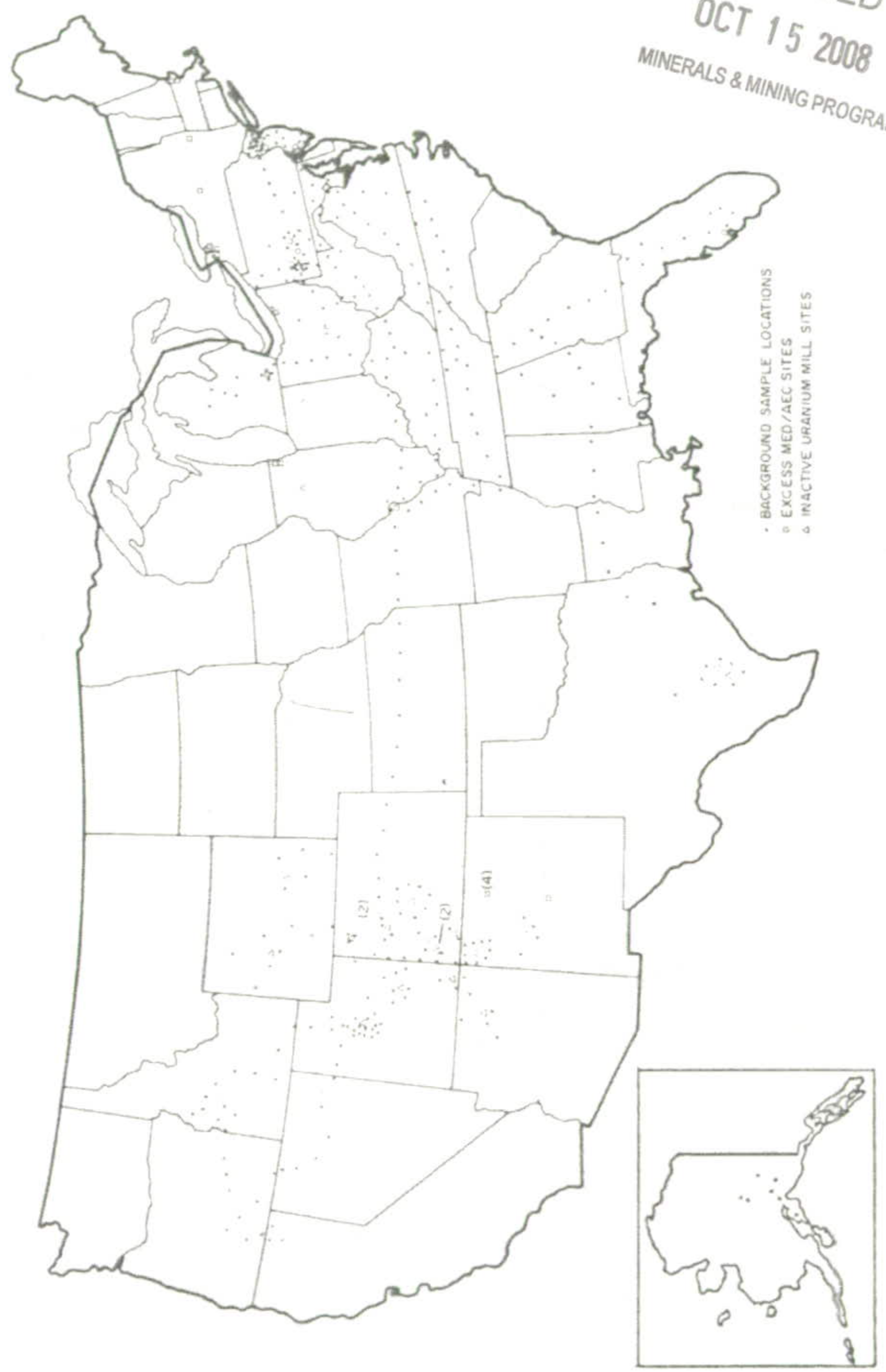

FIG. 1. Location of background soil samples in the U.S.

Alabama	Mississippi
Alaska	Missouri
Arizona	Nevada
Arkansas	New Jersey
California	New Mexico
Colorado	New York
Delaware	North Carolina
Florida	Ohio
Georgia	Oregon
Idaho	Pennsylvania
Illinois	Tennessee
Indiana	Texas
Kansas	Utah
Kentucky	Virginia
Louisiana	West Virginia
Maryland	Wyoming.
Michigan	

Additional sampling within these states, as well as sampling in other states, will occur as radiological surveys continue to be performed in conjunction with the FUSRAP and UMTRAP programs.

RESULTS

Summaries of the state background soil radionuclide concentrations and U.S. averages are provided in Tables 1–3 for ^{226}Ra, ^{232}Th and ^{238}U concentrations, respectively. Included in these tables are the number of data entries for each state as well as the range of values, the arithmetic mean and S.D., and the geometric mean and S.D. The geometric statistical analysis is included since environmental samples are often represented by a lognormal distribution. It should be noted, however, that the geometric S.D. of the mean is not an additive value, but rather is multiplicative. Hence, for these data, values of the geometric S.D. between one and two indicate a "relatively" good fit to the lognormal distribution. The geometric S.D.s reported contain 68% of the frequency values, and represent a 1σ bound. The arithmetic S.D.s are reported as the 95% confidence (or 2σ) values.

The number of sampling locations within any particular state ranges from 1 (in Arkansas) to 33 (in Pennsylvania). Obviously, the characterization of the average background levels in each state is highly dependent upon the sample size, as well as the randomness of the sample, neither of which could be controlled adequately in this measurement program. In addition, local variability in soil types and geologic conditions can result in a wide range of "background" values for any particular area. Therefore, use of the mean state values for comparative purposes must be exercised with caution, as the values reported may not adequately characterize the state as a whole. However, continued sampling, as part of this program, will help to further define both state and regional background levels.

The soil sample analysis resulted in estimates of the mean values for ^{226}Ra, ^{232}Th, and ^{238}U concentrations in surface soil in each of the surveyed states. Figures 2–4 depict the distribution of the state averages, with a strikingly similar pattern occurring for all three radionuclides. This pattern groups the states with lower concentrations generally in the coastal regions, with the higher concentrations occurring in the continental interior states. The state average ^{226}Ra concentration in surface soil was found to vary from 0.65 pCi/g (Alaska) to 1.5 pCi/g (Kentucky, Nevada, New Mexico and Ohio). Relative arithmetic S.D.s ranged from 12 to 158% for the state averages. Individual ^{226}Ra measurements ranged from 0.23 to 4.2 pCi/g. For ^{232}Th, concentrations in individual samples were found from 0.10 to 3.4 pCi/g, with the state averages ranging from 0.24 pCi/g (Florida) to 1.6 pCi/g (Arkansas). Again, the relative arithmetic S.D.s indicate the variability of the sample concentrations and the small sample size, with values of 12–173%. State averages for ^{238}U concentration in surface soil vary from 0.58 pCi/g (Louisiana) to 1.6 pCi/g (Kentucky), with relative arithmetic S.D.s from 8 to 183%. Individual samples had ^{238}U concentrations from 0.12 to 3.8 pCi/g. The average concentrations in the U.S. for all three nuclides were 1.1, 0.98 and 1.0 pCi/g for ^{226}Ra, ^{232}Th and ^{238}U, respectively.

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Table 1. Summary of state background concentrations of ^{226}Ra in surface soil[a]

State	Number of samples analyzed	Range of values (pCi/g)	Arithmetic mean and standard deviation[b] (pCi/g)	Geometric mean and standard deviation[c] (pCi/g)
Alabama	8	0.47 - 1.4	0.82 ± 0.62	0.77:1.5
Alaska	6	0.43 - 0.92	0.65 ± 0.32	0.64:1.3
Arizona	6	0.23 - 2.0	0.95 ± 1.5	0.70:2.4
Arkansas	d	d	d	d
California	3	0.24 - 1.3	0.77 ± 1.0	0.62:2.4
Colorado	32	0.48 - 3.4	1.4 ± 1.1	1.3:1.5
Delaware	2	1.1 - 1.2	1.2 ± 0.14	1.2:1.1
Florida	11	0.25 - 2.3	0.84 ± 1.2	0.67:2.0
Georgia	9	0.46 - 1.6	0.88 ± 0.77	0.81:1.6
Idaho	12	0.64 - 1.6	1.1 ± 0.51	1.1:1.3
Illinois	7	0.65 - 1.2	0.97 ± 0.41	0.95:1.3
Indiana	2	1.0 - 1.1	1.1 ± 0.07	1.1:1.1
Kansas	6	0.34 - 1.4	0.97 ± 0.85	0.86:1.8
Kentucky	13	0.81 - 4.2	1.5 ± 1.7	1.4:1.5
Louisiana	2	0.58 - 0.84	0.71 ± 0.36	0.70:1.3
Maryland	6	0.49 - 1.2	0.72 ± 0.50	0.69:1.4
Michigan	10	0.46 - 2.0	1.1 ± 0.97	0.95:1.6
Mississippi	3	0.77 - 1.6	1.2 ± 0.82	1.2:1.5
Missouri	10	0.31 - 1.4	1.1 ± 0.61	1.0:1.6
Nevada	6	0.89 - 2.0	1.5 ± 0.72	1.5:1.3
New Jersey	24	0.24 - 1.4	0.87 ± 0.67	0.78:1.7
New Mexico	13	0.72 - 2.7	1.5 ± 1.1	1.5:1.4
New York	6	0.48 - 1.2	0.85 ± 0.51	0.81:1.4
North Carolina	8	0.48 - 1.2	0.78 ± 0.48	0.74:1.4
Ohio	12	0.81 - 2.5	1.5 ± 0.93	1.4:1.4
Oregon	8	0.24 - 2.1	0.82 ± 1.1	0.68:1.9
Pennsylvania	33	0.46 - 2.4	1.2 ± 0.75	1.1:1.4
Tennessee	10	0.65 - 1.4	1.1 ± 0.51	1.0:1.3
Texas	10	0.54 - 1.4	0.89 ± 0.54	0.85:1.4
Utah	32	0.53 - 1.9	1.3 ± 0.74	1.2:1.4
Virginia	13	0.60 - 1.1	0.85 ± 0.38	0.83:1.3
West Virginia	11	0.78 - 1.6	1.3 ± 0.57	1.2:1.3
Wyoming	13	0.65 - 1.7	1.0 ± 0.59	1.0:1.3
U. S. Average	327	0.23 - 4.2	1.1 ± 0.48	1.0:1.6

[a] Summary of data contained in My80 for individual states.

[b] Standard deviation of arithmetic mean is the 2σ value.

[c] The geometric standard deviation is a multiplicative parameter to the geometric mean containing 68% (1σ) of the frequency values.

[d] No data on ^{226}Ra concentration available for state.

Table 2. Summary of state background concentrations of ^{232}Th in surface soil

State	Number of samples analyzed	Range of values (pCi/g)	Arithmetic mean and standard deviation[b] (pCi/g)	Geometric mean and standard deviation[c] (pCi/g)
Alabama	8	0.36 - 1.5	0.77 ± 0.71	0.70 : 1.6
Alaska	7	0.19 - 2.3	0.87 ± 1.4	0.67 : 2.2
Arizona	6	0.20 - 1.3	0.63 ± 0.83	0.52 : 2.0
Arkansas	1	1.6	1.6[d]	1.6[d]
California	3	0.30 - 0.76	0.54 ± 0.45	0.50 : 1.6
Colorado	20	0.10 - 3.1	1.3 ± 1.4	1.1 : 2.1
Delaware	2	1.2	1.2 ± 0.04	1.2[d]
Florida	10	0.12 - 0.37	0.24 ± 0.13	0.23 : 1.3
Georgia	9	0.28 - 3.4	1.1 ± 1.9	0.85 : 2.1
Idaho	13	0.42 - 1.9	1.2 ± 0.73	1.1 : 1.5
Illinois	8	0.49 - 1.2	0.96 ± 0.43	0.93 : 1.3
Indiana	2	1.1 - 1.2	1.2 ± 0.14	1.2 : 1.1
Kansas	4	0.32 - 1.6	1.3 ± 1.2	1.1 : 2.2
Kentucky	12	0.88 - 1.5	1.2 ± 0.39	1.2 : 1.2
Louisiana	2	0.60 - 0.72	0.66 ± 0.17	0.66 : 1.1
Maryland	6	0.48 - 0.86	0.70 ± 0.28	0.69 : 1.2
Michigan	10	0.24 - 0.82	0.56 ± 0.35	0.53 : 1.5
Mississippi	3	0.81 - 1.7	1.1 ± 0.50	1.1 : 1.5
Missouri	10	0.32 - 1.3	1.0 ± 0.56	0.95 : 1.5
Nevada	6	0.62 - 3.0	1.5 ± 1.6	1.4 : 1.7
New Jersey	23	0.31 - 1.5	0.90 ± 0.66	0.82 : 1.6
New Mexico	13	0.48 - 1.8	0.95 ± 0.73	0.89 : 1.5
New York	6	0.40 - 1.1	0.71 ± 0.52	0.67 : 1.5
North Carolina	8	0.42 - 1.5	0.92 ± 0.83	0.83 : 1.6
Ohio	12	0.71 - 1.5	1.0 ± 0.50	1.0 : 1.3
Oregon	9	0.43 - 1.5	0.72 ± 0.66	0.66 : 1.5
Pennsylvania	33	0.38 - 1.7	1.1 ± 0.53	1.1 : 1.3
Tennessee	11	0.66 - 1.5	0.95 ± 0.50	0.92 : 1.3
Texas	10	0.40 - 1.1	0.73 ± 0.40	0.70 : 1.4
Utah	28	0.20 - 2.3	1.1 ± 0.92	0.97 : 1.7
Virginia	13	0.42 - 1.4	0.86 ± 0.47	0.83 : 1.4
West Virginia	11	1.1 - 1.6	1.4 ± 0.35	1.3 : 1.2
Wyoming	12	0.59 - 1.8	1.1 ± 0.68	1.0 : 1.4
U. S. Average	331	0.10 - 3.4	0.98 ± 0.46	0.87 : 1.7

[a]Summary of data contained in My80 for individual states.

[b]Standard deviation of arithmetic mean is the 2σ value.

[c]The geometric standard deviation is a multiplicative parameter to the geometric mean containing 68% (1σ) of the frequency values.

[d]Values for standard deviation cannot be computed.

Table 3. Su

State
Alabama
Alaska
Arizona
Arkansas
California
Colorado
Delaware
Florida
Georgia
Idaho
Illinois
Indiana
Kansas
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Maryland
Michigan
Mississippi
Missouri
Nevada
New Jersey
New Mexico
New York
North Carolina
Ohio
Oregon
Pennsylvania
Tennessee
Texas
Utah
Virginia
West Virginia
Wyoming
U. S. Average

[a]Summary o

[b]Standard

[c]The geomet
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Geometric mean and standard deviation[b] (pCi/g)
0.70 : 1.6
0.67 : 2.2
0.52 : 2.0
1.6[d]
0.50 : 1.6
1.1 : 2.1
1.2[d]
0.23 : 1.1
0.85 : 2.1
1.1 : 1.5
0.93 : 1.3
1.2 : 1.1
1.1 : 2.7
1.2 : 1.2
0.66 : 1.1
0.69 : 1.2
0.53 : 1.5
1.1 : 1.5
0.95 : 1.5
1.4 : 1.7
0.82 : 1.6
0.89 : 1.5
0.67 : 1.5
0.83 : 1.6
1.0 : 1.3
0.66 : 1.5
1.1 : 1.3
0.92 : 1.3
0.70 : 1.4
0.97 : 1.7
0.83 : 1.4
1.3 : 1.2
1.0 : 1.4
0.87 : 1.7

to the geo-

Table 3. Summary of state background concentrations of ^{238}U in surface soil

State	Number of samples analyzed	Range of values (pCi/g)	Arithmetic mean and standard deviation[b] (pCi/g)	Geometric mean and standard deviation[c] (pCi/g)
Alabama	8	0.51 - 1.1	0.85 ± 0.36	0.83 : 1.3
Alaska	7	0.39 - 0.80	0.63 ± 0.30	0.61 : 1.3
Arizona	6	0.27 - 1.83	0.82 ± 1.1	0.67 : 2.0
Arkansas	1	1.5	1.5	1.5[d]
California	3	0.19 - 1.3	0.78 ± 1.1	0.59 : 2.7
Colorado	32	0.47 - 3.0	1.2 ± 0.91	1.2 : 1.4
Delaware	2	1.1 - 1.2	1.2 ± 0.10	1.2 : 1.0
Florida	11	0.12 - 2.0	0.71 ± 1.3	0.47 : 2.7
Georgia	9	0.48 - 1.6	0.85 ± 0.72	0.79 : 1.5
Idaho	13	0.66 - 2.2	1.1 ± 0.88	1.1 : 1.4
Illinois	8	0.64 - 1.4	1.1 ± 0.45	1.0 : 1.3
Indiana	2	1.1 - 1.4	1.3 ± 0.31	1.3 : 1.1
Kansas	6	0.58 - 1.4	1.1 ± 0.60	1.0 : 1.4
Kentucky	13	1.1 - 3.8	1.6 ± 1.4	1.5 : 1.4
Louisiana	3	0.44 - 0.81	0.58 ± 0.40	0.56 : 1.4
Maryland	6	0.54 - 0.93	0.78 ± 0.30	0.77 : 1.2
Michigan	10	0.34 - 1.2	0.73 ± 0.55	0.68 : 1.5
Mississippi	3	0.69 - 1.7	1.1 ± 1.1	0.98 : 1.6
Missouri	10	0.33 - 1.7	1.1 ± 0.73	0.99 : 1.6
Nevada	6	0.74 - 1.8	1.3 ± 0.65	1.3 : 1.3
New Jersey	24	0.13 - 1.4	0.86 ± 0.68	0.76 : 1.8
New Mexico	13	0.53 - 1.5	1.1 ± 0.55	1.0 : 1.3
New York	6	0.76 - 1.2	0.95 ± 0.26	0.94 : 1.2
North Carolina	8	0.39 - 1.6	0.87 ± 0.71	0.81 : 1.5
Ohio	12	0.76 - 2.2	1.4 ± 0.79	1.3 : 1.4
Oregon	9	0.50 - 2.0	0.84 ± 0.89	0.76 : 1.5
Pennsylvania	33	0.41 - 1.9	1.2 ± 0.59	1.1 : 1.4
Tennessee	12	0.72 - 1.3	1.0 ± 0.39	1.0 : 1.2
Texas	10	0.48 - 1.5	0.82 ± 0.59	0.78 : 1.4
Utah	32	0.46 - 2.4	1.1 ± 0.82	1.0 : 1.4
Virginia	13	0.68 - 1.3	0.95 ± 0.34	0.94 : 1.2
West Virginia	11	1.1 - 1.8	1.4 ± 0.53	1.4 : 1.2
Wyoming	13	0.66 - 1.9	1.0 ± 0.63	0.97 : 1.3
U. S. Average	355	0.12 - 3.8	1.0 ± 0.83	0.96 : 1.6

[a]Summary of data contained in My80 for individual states.

[b]Standard deviation of arithmetic mean is the 2σ value.

[c]The geometric standard deviation is a multiplicative parameter to the geometric mean containing 68% (1σ) of the frequency values.

[d]Values for geometric standard deviation cannot be computed.

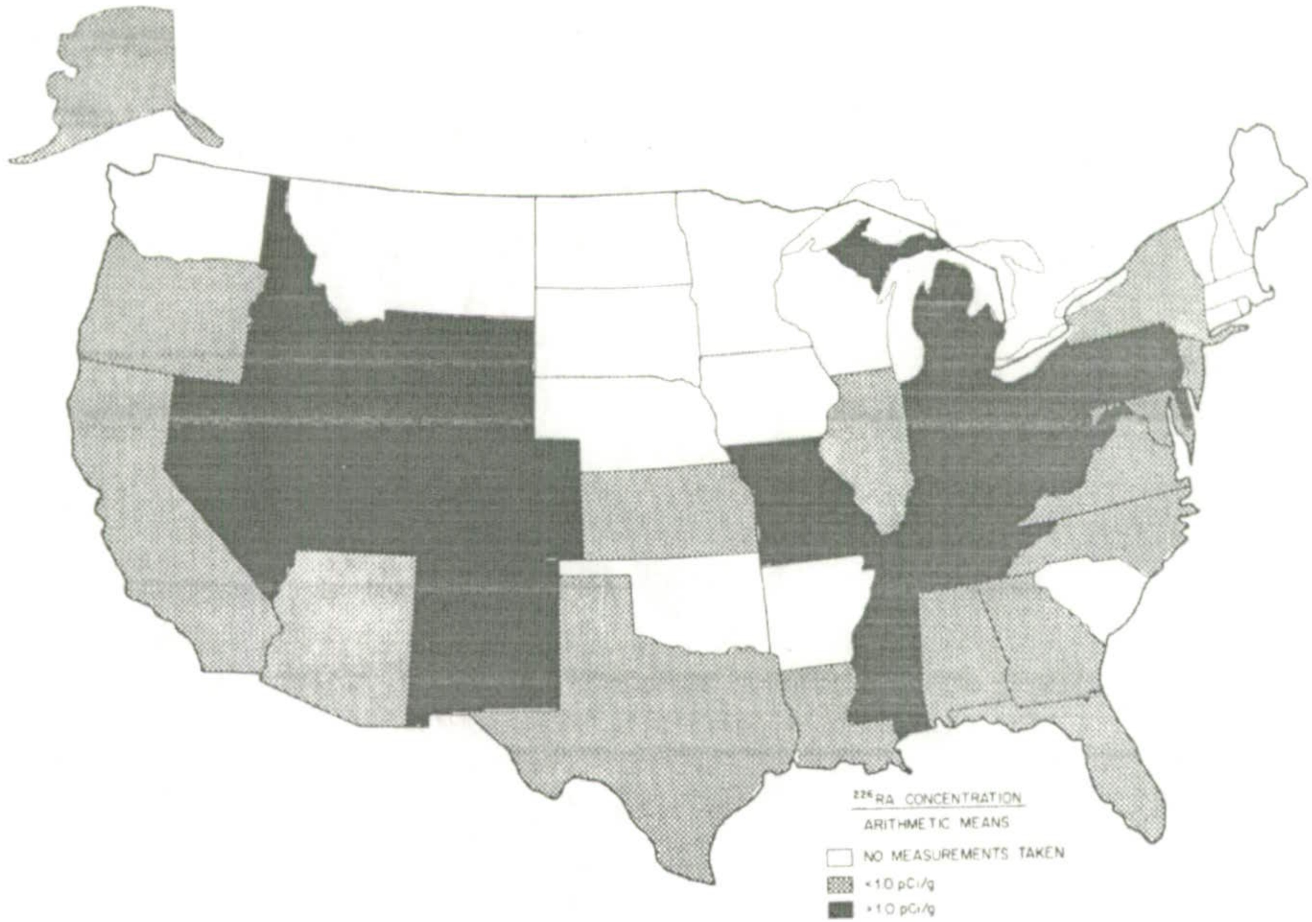

FIG. 2. Concentration of ^{226}Ra in surface soil samples—state averages.

FIG. 2. Concentration of ^{226}Ra in surface soil samples—state averages.

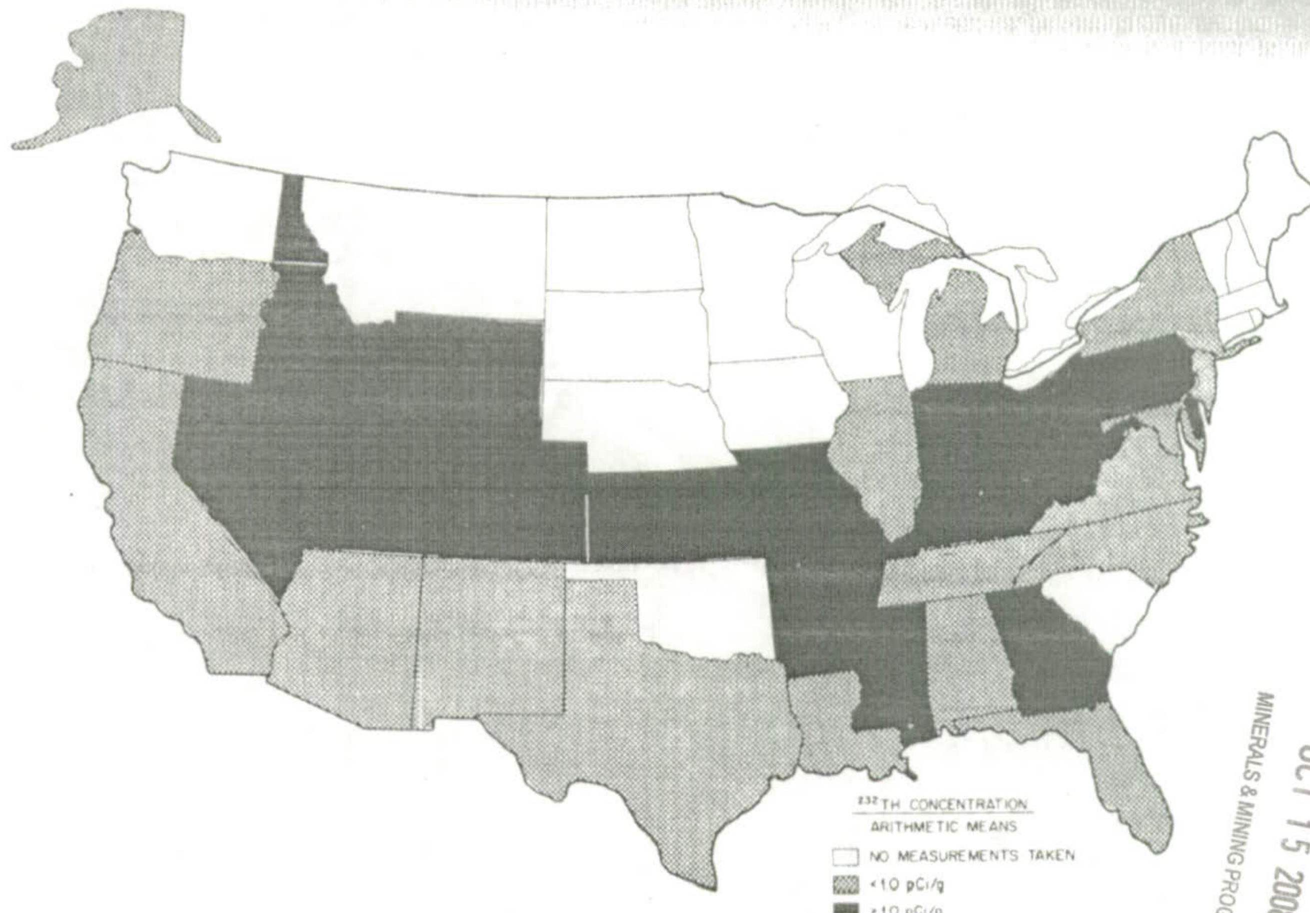

FIG. 3. Concentration of ^{232}Th in surface soil samples—state averages.

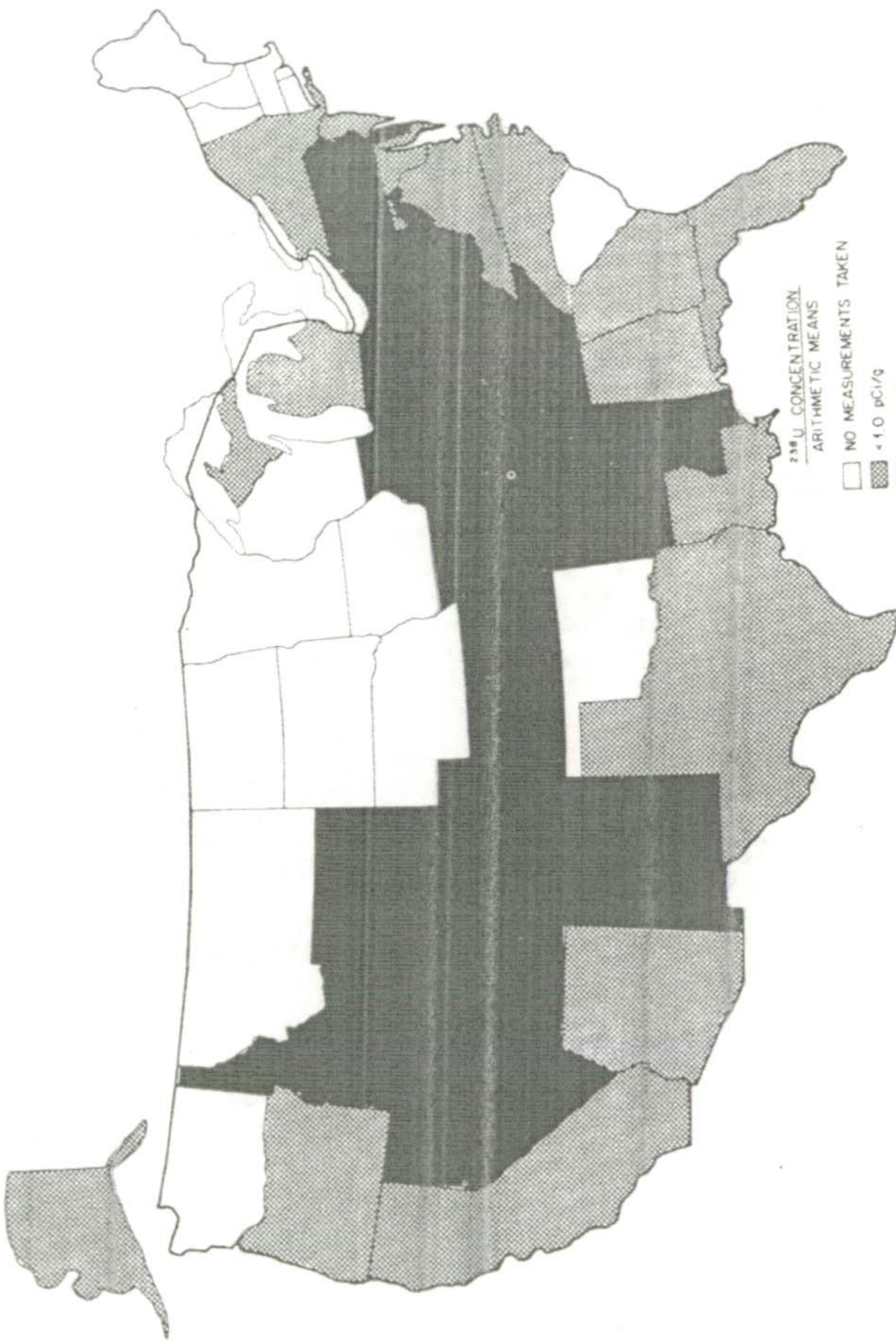

FIG. 4. Concentration of ^{238}U in surface soil samples—state averages.

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A common feature in radiation measurement determination of radior and concentrations in si this type have been recent years by many large and varied data b marized by the United Committee on the Effec tion in a number of repo its UNSCEAR 1977 editi

The natural radioactiv upon that of the parent soil formation and trar were involved. In the c weathering and soil form biochemical interactions tribution patterns of uran well as all the radionucl radioactive decay of thes uranium, thorium and ra wide variety of soils in Europe are listed in Tabl concentrations are a str type and soil horizon, wi tion of soil radioactivity depth being common (obtained during the me presented in this paper with the literature value concentrations for ^{226}Ra, 0.98 and 1.0 pCi/g fall observed values and are the tabulated world avera

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Table 4. Background radionu surface soil–Worl

Radionuclide	Radionu
	Typical ran
^{226}Ra	0.49-1.98
^{238}U	0.33-1.32
^{232}Th	0.22-1.31

[a] Adapted from NCRP76.

FIG. 4. Concentration of ^{238}U in surface soil samples—state averages.

DISCUSSION

Isotopic distribution of radionuclides in soil

A common feature in many environmental radiation measurement programs is the determination of radionuclide distributions and concentrations in surface soil. Data of this type have been accumulated during recent years by many investigators. This large and varied data base has been summarized by the United Nations Scientific Committee on the Effects of Atomic Radiation in a number of reports, most recently in its UNSCEAR 1977 edition (UN77).

The natural radioactivity of soil depends upon that of the parent rock as well as the soil formation and transport process that were involved. In the course of such rock weathering and soil formation, chemical and biochemical interactions influence the distribution patterns of uranium and thorium, as well as all the radionuclides created by the radioactive decay of these elements. Typical uranium, thorium and radium contents of a wide variety of soils in North America and Europe are listed in Table 4. These observed concentrations are a strong function of soil type and soil horizon, with significant variation of soil radioactivity with location and depth being common (Ba73). The values obtained during the measurement program presented in this paper compare favorably with the literature values. The mean U.S. concentrations for ^{226}Ra, ^{238}U and ^{232}Th of 1.1, 0.98 and 1.0 pCi/g fall within the range of observed values and are only slightly above the tabulated world averages.

The relatively few simultaneous measurements of the uranium and radium concentrations in soil indicate that radioactive equilibrium is roughly obtained in many soils, but large deviations from equilibrium are also observed due to the different geochemical properties of uranium and radium compounds (NCRP76). Departure from equilibrium occurs even more readily for those ^{238}U daughters beyond ^{222}Rn because of the escape of gaseous radon from the soil matrix. The correlation between the radium and uranium concentration data presented in the previous section was computed for 346 sampling locations where simultaneous measurements had been made. The correlation coefficent for these data was determined to be 0.77, indicating good correlation, especially for field measurements. The U.S. average concentrations of radium and uranium showed a nearly 1:1 correlation, signifying that at least on such a gross level, radioactive equilibrium exists.

Table 4. Background radionuclide concentrations in surface soil–World averages

Radionuclide	Radionuclide concentration in soil (pCi/g)	
	Typical range	World average
^{226}Ra	0.49-1.98	0.79
^{238}U	0.33-1.32	0.66
^{232}Th	0.22-1.31	0.65

[a]Adapted from NCRP76.

CONCLUSIONS

Based on the results to date of the ORNL background measurement program, regional differences in radionuclide concentrations (^{226}Ra, ^{238}U and ^{232}Th) in surface soil are evident. Radioactive equilibrium within the uranium decay series was found to exist in most soil samples analyzed, with a 1:1 correlation between average ^{238}U and ^{226}Ra concentrations for the country as a whole.

Additional soil sampling will be taken as ORNL's participation in DOE's radiological survey programs continues. These data will help to further define both state and regional natural background levels.

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Health Physics Vol. 45, No. 3 (Septen
Printed in the U.S.A.

^{90}Sr AND
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